Abdullah, N. F., Piechocki, R. J., & Doufexi, A. (2010). Spatial diversity for IEEE 802.11p V2V safety broadcast in a highway environment. In ITU Workshop on Fully Networked Car, Geneva. International Telecommunication Union (ITU).

Spatial Diversity for IEEE 802.11p V2V Safety Broadcast in a Highway Environment

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Need for Vehicular Communication...

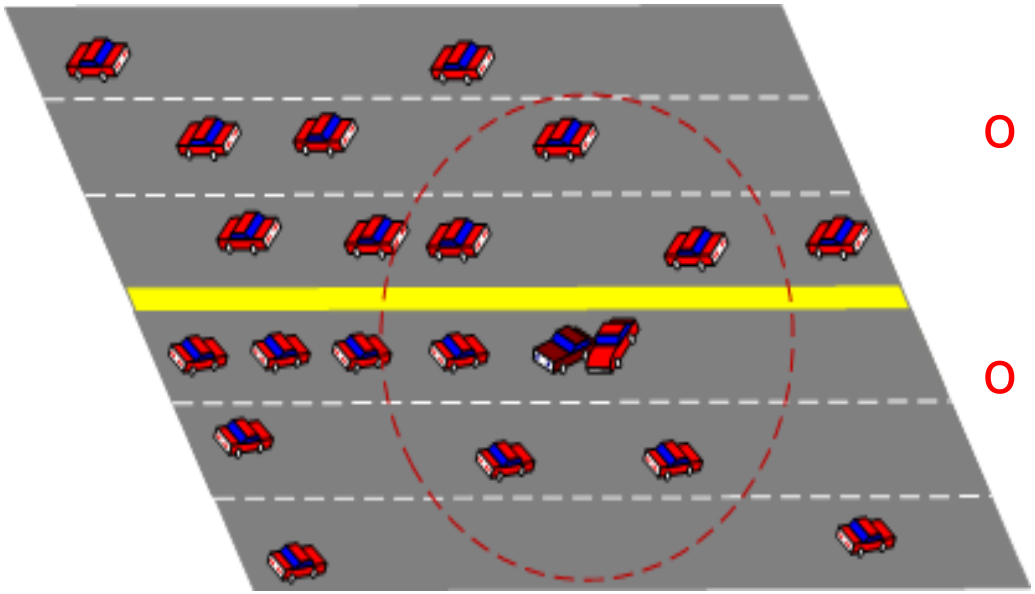
- In 2007, the EU recorded ~43,000 deaths and >1.8 million injuries (€160 billion loss)
- Steady growth of car usage and ownership (>200 millions cars in Europe)
  - congestion built-up, unpredictable journey time
  - impact on the economy: significant vehicle operating costs overhead, burden for travellers
  - impact on the environment: harmful emissions, worsen air quality
- Allocated bandwidth for C2X services
- Lowering cost of WiFi and GPS

European Road Safety Observatory, Annual statistical report 2007. [Online] http://euroris.swov.nl/safetynet/xed/WP1/2007/SN-1-3-ASR-2007.pdf

Research Contribution

- Vehicular communication requires longer communication range (than 802.11a/g/n), in extreme multipath and high speed environment
  - Spatial diversity: a low complexity and low cost solution
- Accurate and realistic vehicular communication modelling by means of:
  - BER curves from detailed PHY simulator specific to modulation types, vehicular speeds and range of SNR values
  - Integration of PHY simulator and realistic mobility model into network simulator

Scenario: Post-crash warning in highway environment



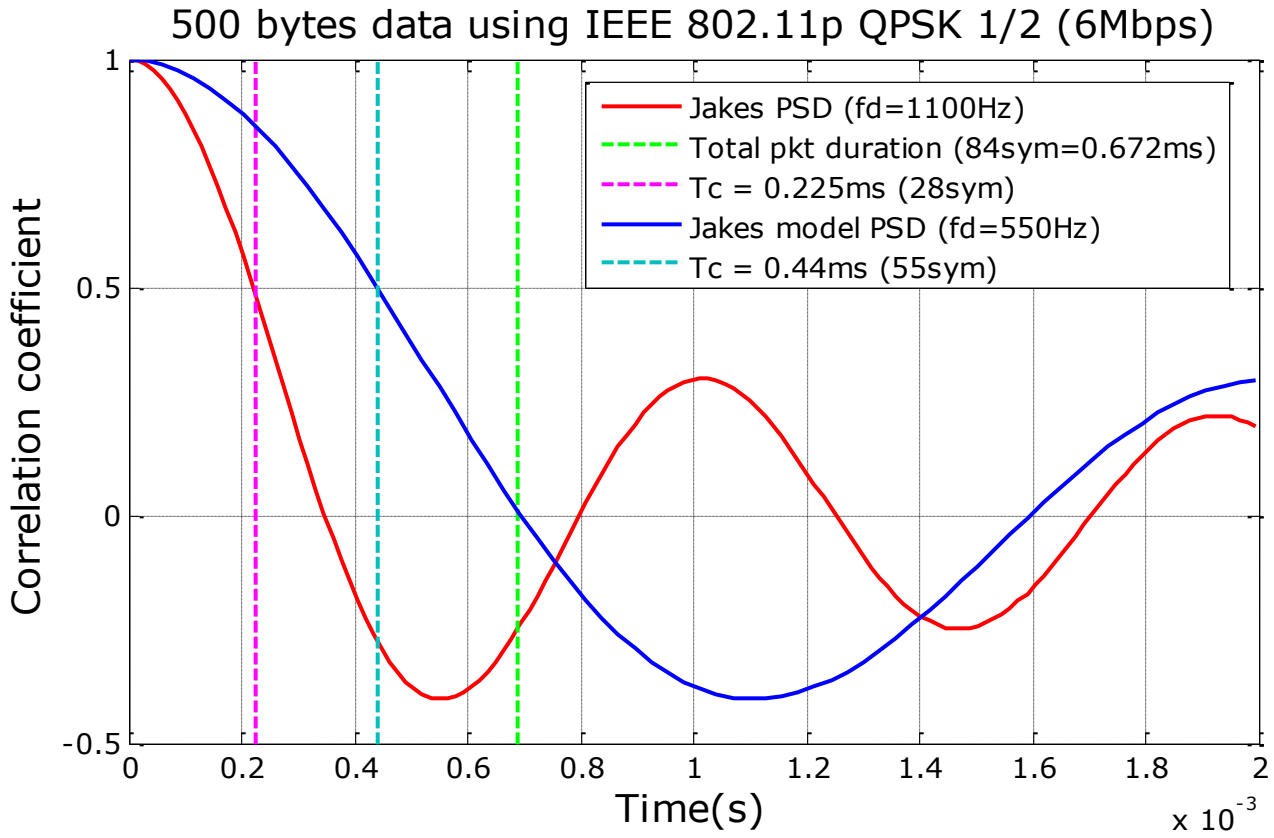
- Realistic mobility traces: 3 lanes bidirectional highway.
- 2 types of traffic density models (Low & High).
- 2 types of ad-hoc V2V safety messages
  - Emergency message
  - Periodic message
- Rayleigh channel with 103ns rms delay spread (ETSI channel B)

D. W. Matolak, I. Sen, W. Xiong, and N. T. Yaskoff, "5GHZ Wireless Channel Characterization for Vehicle to Vehicle Communications," Proceedings of IEEE Military Communications Conference (MILCOM '05), vol. 5, pp. 3022–3016, Atlatnic City, NJ, USA, Oct 2005.

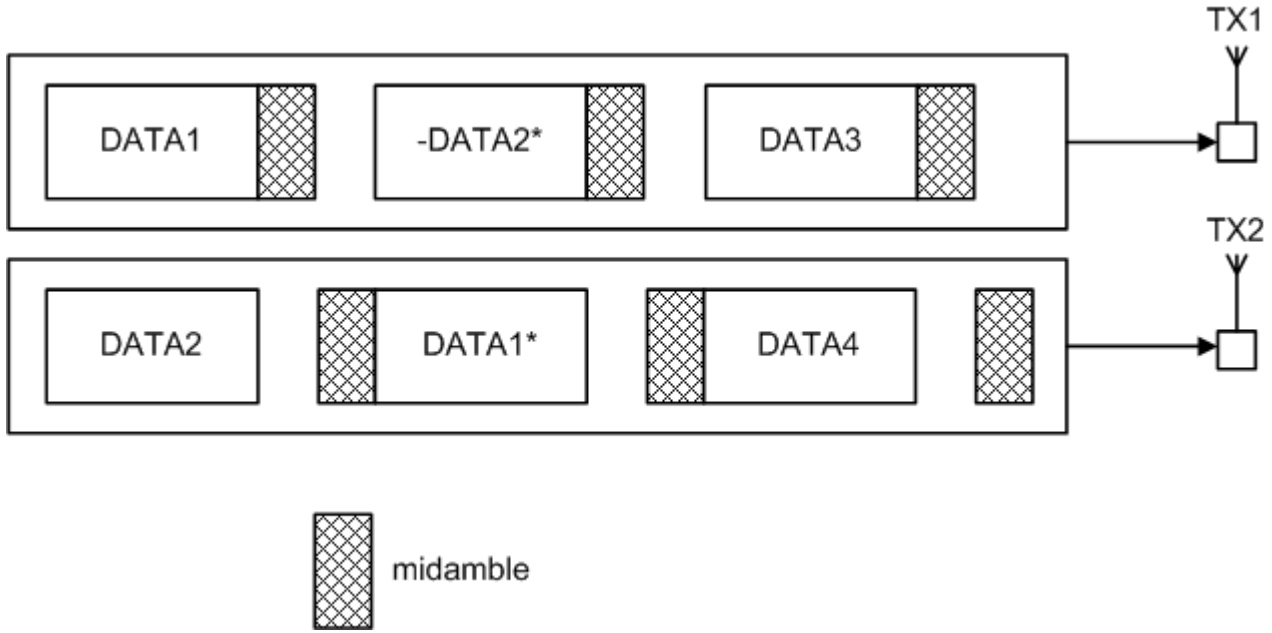
Midamble symbol spacing as a function of channel coherence time, data rate, and packet size

Space-time correlation, $\rho(\Delta t) = J_0(2\pi f_d v \Delta t)$

Midamble spacing chosen: 30 symbols



Frame Structure for Proposed Multi Antenna System with Midamble Channel Estimation

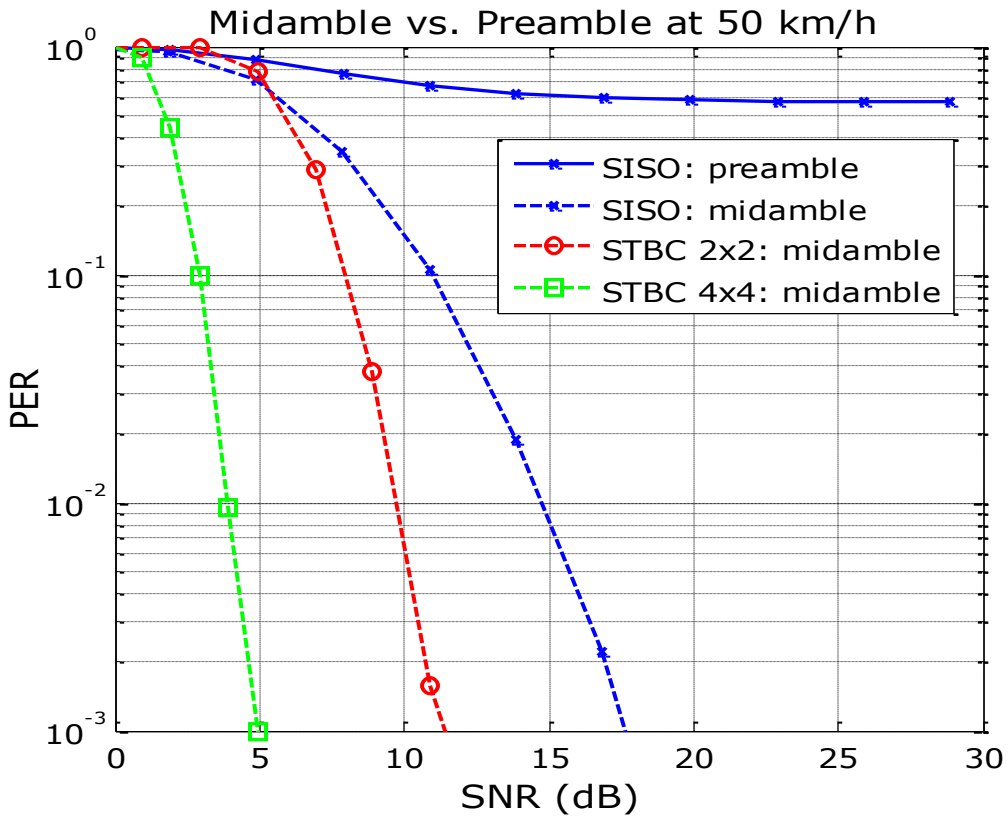


- Channel tracking: reuses long preamble sequence for midamble channel estimation

S. I. Kim, H. S. Oh, and H. K. Choi, "Mid-amble Aided OFDM Performance Analysis in High Mobility Vehicular Channel," *IEEE Intelligent Vehicles Symposium, Eindhoven, Netherlands, Jun 2008.*

Need for midamble in fast fading vehicular channel

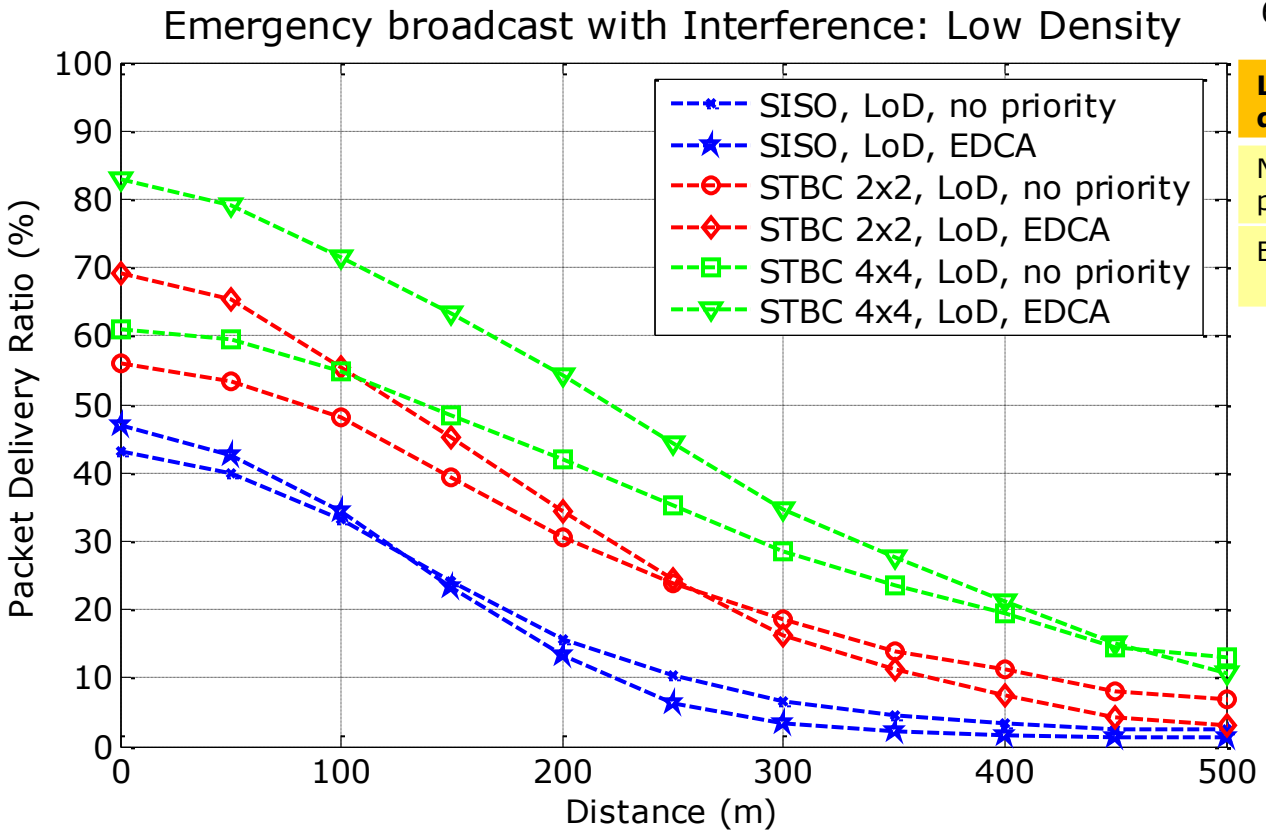
- Midamble vs. Preamble at 10 symbols midamble spacing



SISO: Single Input Single Output
STBC: Space Time Block Codes
Modulation: QPSK 1/2

Antenna configuration	Rank
SISO	1
STBC 2x2	1
STBC 4x4	3/4

Low Density Traffic: Emergency Message Packet Delivery Ratio in Rayleigh channel

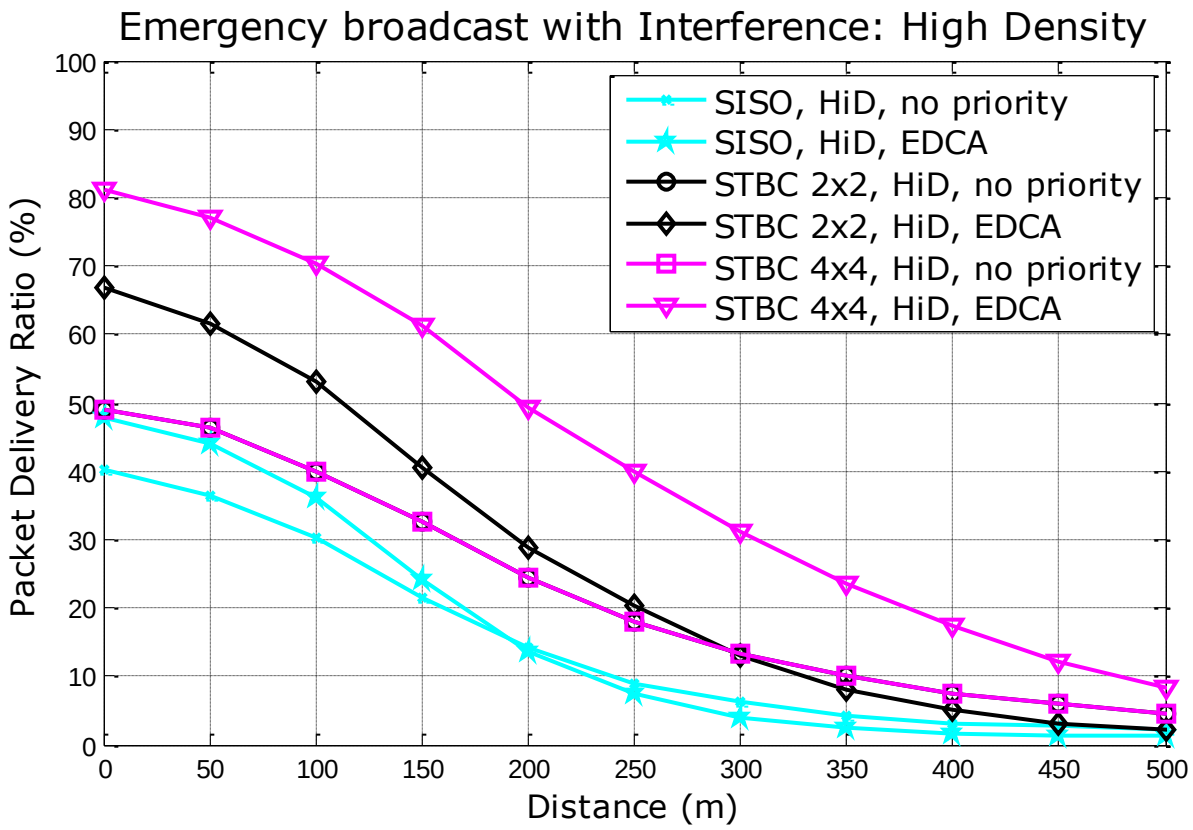


Low density traffic:
6 vehicles/km/lane

Low density	STBC 2x2 vs. SISO	STBC 4x4 vs. SISO
No priority	60% (200m/125m)	132% (290m/125m)
EDCA	80% (225m/125m)	164% (330m/125m)

* EDCA (Enhanced Distributed Channel Access)

High Density Traffic: Emergency Message Packet Delivery Ratio in Rayleigh channel



High density traffic:
11 vehicles/km/lane

High density	**STBC 2x2 vs. SISO**	**STBC 4x4 vs. SISO**
No priority	**70%** (170m/100m)	65% (165m/100m)
EDCA	50% (195m/130m)	138% (310m/130m)
Low density	**STBC 2x2 vs. SISO**	**STBC 4x4 vs. SISO**
No priority	60% (200m/125m)	**132%** (290m/125m)
EDCA	**80%** (225m/125m)	**164%** (330m/125m)

High density	**STBC 2x2 vs. SISO**	**STBC 4x4 vs. SISO**
EDCA improvement	**15%** (195m/170m)	**88%** (310m/165m)
Low density	**STBC 2x2 vs. SISO**	**STBC 4x4 vs. SISO**
EDCA improvement	13% (225m/200m)	14% (330m/290m)

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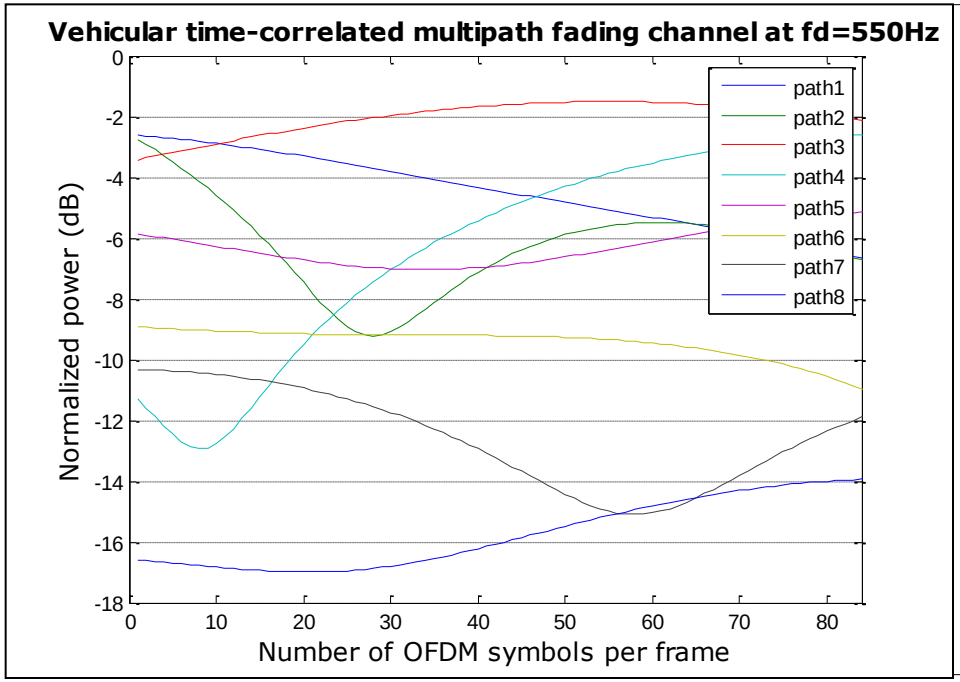
Conclusion

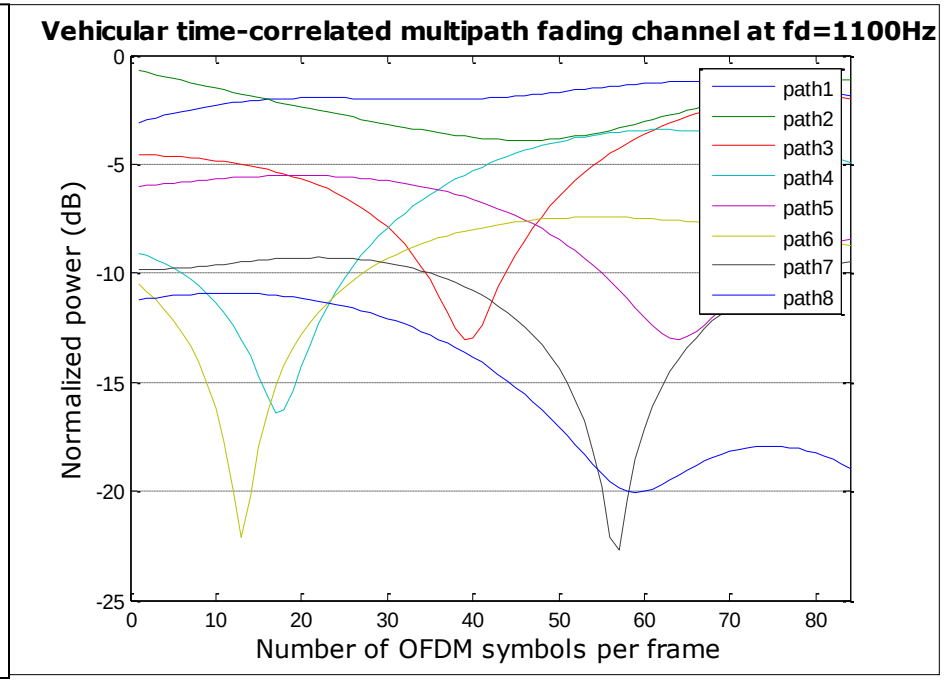
- Performance of safety broadcast messages, for MIMO-STBC vs. SISO in a vehicular environment has been presented.
- Spatial diversity increase the communication range: 50-80% for STBC 2x2 and 65-164% for STBC 4x4 case.
- Traffic prioritization (EDCA) is efficient in high density scenario and extends the communication range by 15% for STBC 2x2 case and 88% for STBC 4x4.

Appendix

Vehicular Channel Model

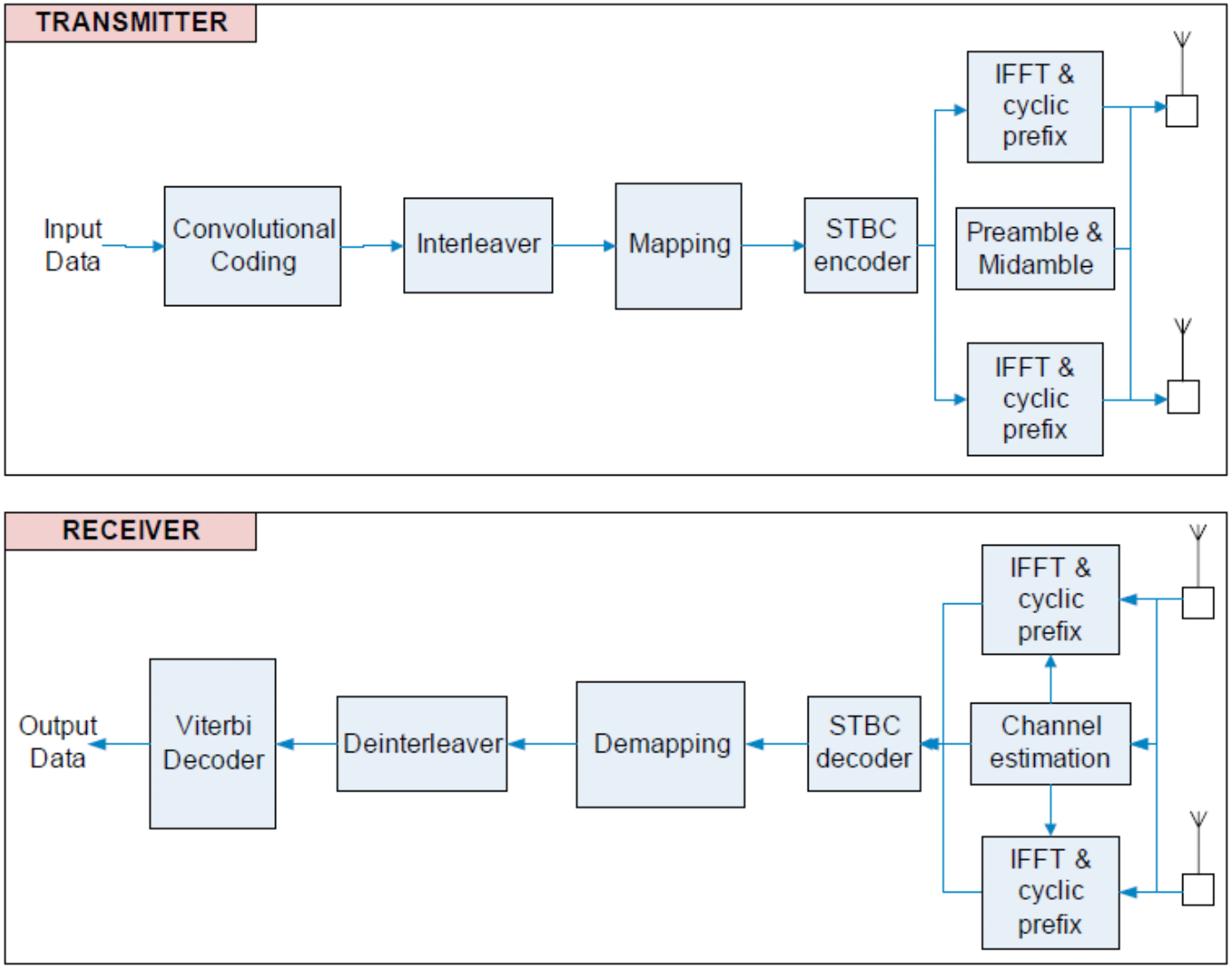
- Differing maximum Doppler shifts for low and high density traffic
- RMS delay spread of 103ns [Matolak, 2005]





D. W. Matolak, I. Sen, W. Xiong, and N. T. Yaskoff, "5GHZ Wireless Channel Characterization for Vehicle to Vehicle Communications," Proceedings of IEEE Military Communications Conference (MILCOM '05), vol. 5, pp. 3022–3016, Atlatnic City, NJ, USA, Oct 2005.

Physical Layer Simulator Block Diagram



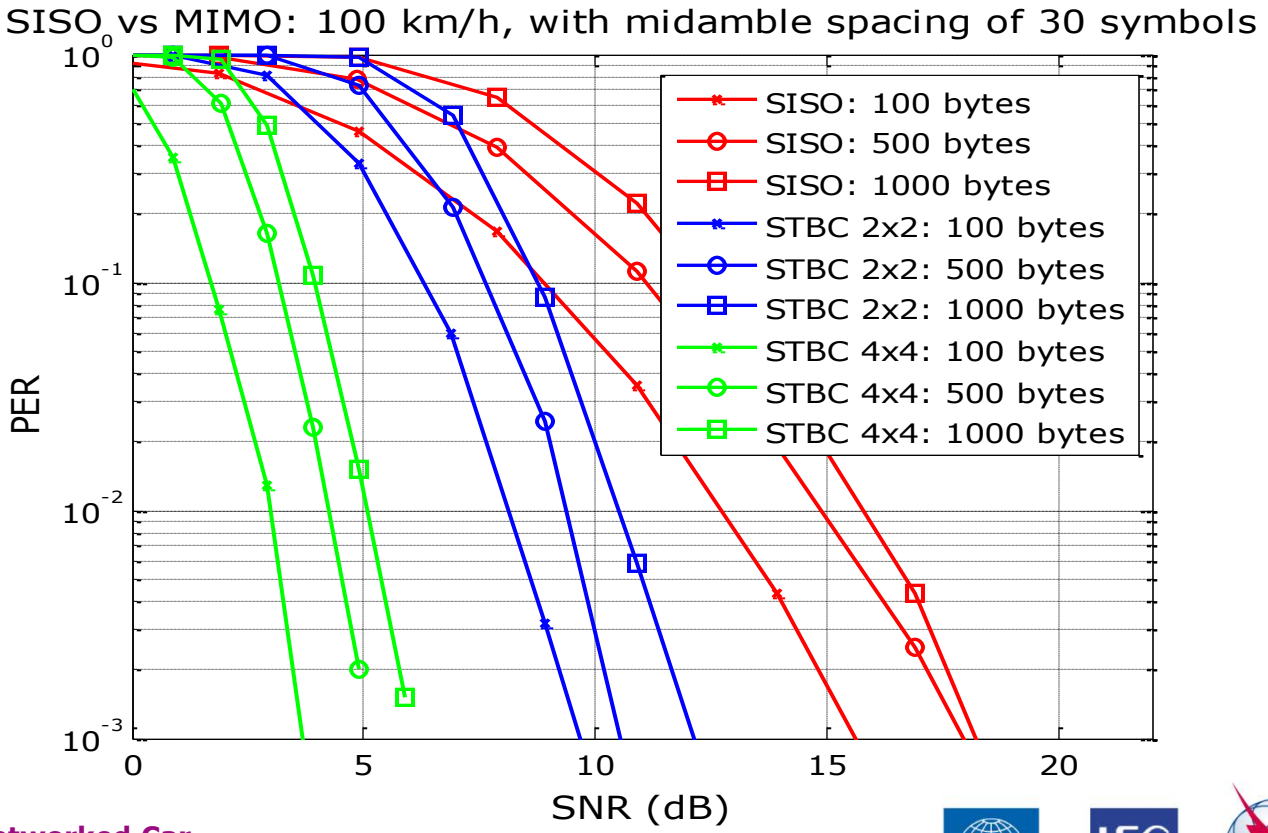
Numerical Analysis Parameters

Physical Layer	MAC Layer
Tx Frequency: 5.9 GHz	Slot Time: 13 us
Bandwidth: 10 MHz	OFDM symbol: 8 us
Tx Power: 23 dBm	PLCP: 40 us
Receiver threshold: -82 dBm	SIFS: 32 us, CWmin: 31
Antenna gain: 0 dBi	DIFS: 58 us, BO = 208 us
Antenna height : 1.5 m	EDCA: High Priority (EM)
Channel Model: Rayleigh	ECWmin: 7
Modulation scheme: QPSK 1/2	AIFS: 58 us, BO = 52 us
Application Layer	EDCA: Low priority (PM)
Pkt Generation Rate: 10 pkt/s	ECWmin: 31
Packet size: 500 bytes	AIFS: 123 us, BO = 208 us

Midamble symbol spacing as a function of channel coherence time, data rate, and packet size

Lower SNR requirement for higher spatial diversity and smaller payload size.

- STBC 4x4 reduces maximum data rate



Midamble symbol spacing as a function of channel coherence time, data rate, and packet size

Higher SNR requirement for higher modulations.